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Research Article

Protective effect of chitosan coating and polyethylene film wrapping on postharvest storage of sugar-apples

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Abstract

Sugar-apples (*Annona squamosa*) were harvested immediately after reaching maturity, washed and dipped in dissolved chitosan. After air-drying, the fruit were individually wrapped in polyethylene film and stored at 10^{0}C. Sugar-apples coated with 2% chitosan and wrapped in polyethylene showed up to a 30% lower ripening rate compared to wrapped-only or non-protected controls. In addition, it was found that chitosan treated sugar-apples maintained their quality better and preserved high sensory and nutrient qualities during a storage period of 12 days at 10^{0}C.

Keywords: packaging, *Annona squamosa*, deacetylation, Vietnam.

Introduction

Sugar-apples (*Annona squamosa* L.), also known as custard apples, belong to the genus *Annonaceae* and are one of the most popular tropical fruit in Asia. It has been ranked in Vietnam as a product with good export potential. However, sugar-apples are climacteric and have a very short storage life due to their fast ripening after harvest [1, 2, 3]. The softening and reduction of firmness of the fruit are the main reasons for the decrease in quality and the major drawback to developing an export market for this fruit [4, 5]. Therefore it is important to improve the preservation of the whole fruit and to extend its storage life.

In addition to chemical and other treatments [6], storability of perishable crops has been shown to be improved by the application of semi-permeable coatings [7, 8]. Coating can delay fruit ripening of cherimoya, bananas and pears through modifying the internal atmosphere [9, 10, 11]. Similar results have been obtained in pears and apples using edible coatings [10, 12].

Figure 1. *Annona squamosa* or sugar apple.
(Source: Wikimedia Commons)

Chitosan is a high molecular weight polysaccharide. It is the deacetylated derivative of chitin, the skeletal biopolymer in shellfish carapace. In application, usually chitosan with a degree of deacetylation of 70-90% is used. The deacetylation results in the formation of many free amine groups that give chitosan its polycationic character that makes it possible to dissolve chitosan in diluted acid. Chitosan dissolved in diluted organic acids can be used as a casting fluid to form a preservative membraneous coating on fruit. The coating is food safe [13], and shows antifungal activity against several fungi [14, 15, 16]. Previous studies indicate that chitosan coating has the potential to prolong storage life and to delay the decay of many fruit, such as strawberries, peaches and table grapes [17, 18, 19]. Polyethylene wrapping is also a common method for preservation of fresh fruit [20, 21, 22]. In this research project, the effect of chitosan coating and polyethylene film wrapping on quality and storage of sugar-apples (*Annona squamosa* L.) has been investigated.

Materials and Methods

Mature sugar-apples were harvested from an orchard in Tay Ninh Province, Vietnam and washed in water. Fruit were selected for uniformity, shape, colour and size. Any blemished or diseased fruit was discarded.

Chitosan with a degree of deacetylation 75% and a molecular weight of 1,200,000 Dalton was supplied by Nha Trang University, Vietnam. Coating solutions were prepared by dissolving 2% chitosan in 1% (w/v) lactic acid. The pH of the solutions was adjusted to pH 6.5 with 1M NaOH. Sugar-apples were individually dipped in the chitosan solution for 1 min and allowed to dry in air at room temperature for 2 h.

Following this, each fruit was wrapped in polyethylene film and stored at 10^{o}C. Non-coated non-wrapped fruit served as control.

Samples of the treated and non-treated fruit were taken randomly every 3 days to analyze colour, weight loss, respiration rate, total sugar, titratable acidity and ascorbic acid content. Changes in colour of the peel were measured using a Minolta Chroma Meter CR-400 (Japan). Weight loss was determined by direct weighing. The percentage of weight loss was calculated with respect to the initial weight. Respiration rate of fruit was investigated by measuring the oxygen consumption rate [23]. Total sugar was measured by the phenol-sulphuric acid method [24]. Titrable acidity (as g/100 g) of citric acid was determined by the titrimetric method [25]. Ascorbic acid content was determined by 2,6-dichlor-ophenolindophenol titration [26].

All the results presented are the mean value of three replicates. Analysis of variance was performed using Microsoft Excel.

Results and Discussion

Effect of chitosan coating on the colour of the peel of sugar-apples

Changes in the colour of sugar-apples were monitored by measuring lightness values (L value) and hue angle during 12 days of storage at 10^0C. Values are recorded in Figs. 2 and 3. Fruit coated with chitosan and wrapped in film darkened only slightly as evidenced by decreasing L values. Wrapping in polyethylene film only resulted in more change in L value.

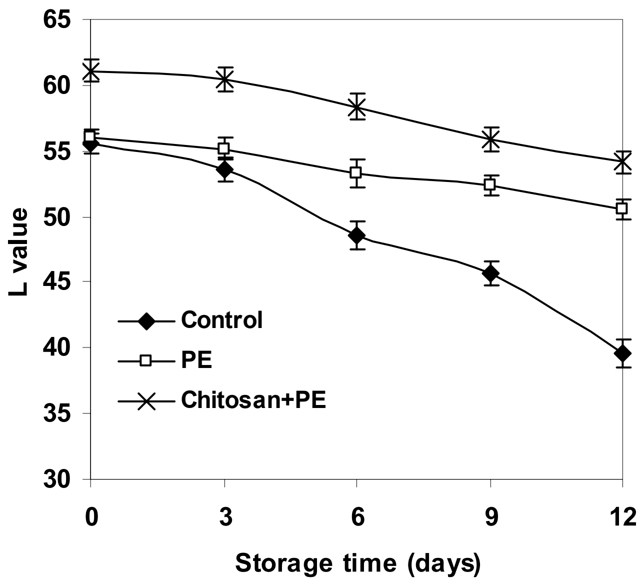

Figure 2. Effect of chitosan coating in combination with wrapping in polyethylene film (PE) on changes in lightness L value of sugar-apples during storage at 10^0C, compared with effect of polyethylene wrapping PE only and with control (no protective treatment).
Each value is the mean for five replicates, and vertical bars indicate the standard deviation.

Coated and uncoated fruit samples showed a significant decrease in hue angle after 3 days of storage (Fig. 3). The uncoated sugar-apples were found to have a faster rate in decrease of hue angle, as compared with coated sugar-apples.

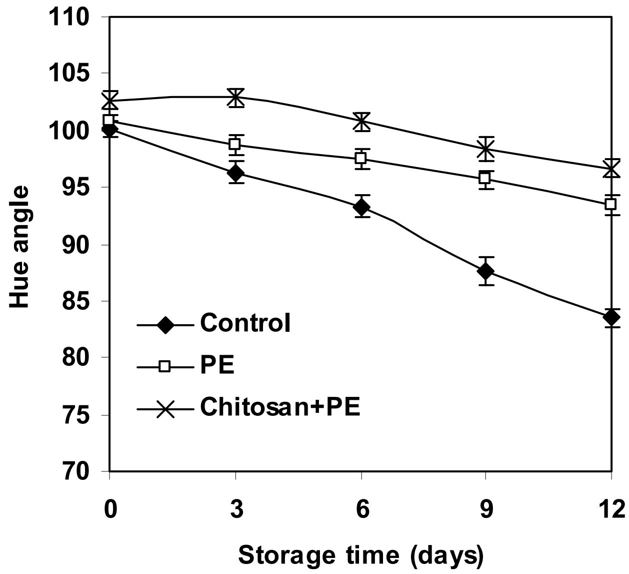

Figure 3. Effect of chitosan coating in combination with wrapping in polyethylene film (PE) on changes in hue angle of sugar-apples during storage at 10^{0}C, compared with effect of polyethylene wrapping PE only and with control (no protective treatment).
Each value is the mean for five replicates, and vertical bars indicate the standard deviation.

Peel colour scores of fruit in polyethylene film containing an ethylene scavenger remained "more green than yellow" until 12 days, this result is consistent with results observed by Jiang, *et al* [27].

Apparently, chitosan coating can delay peel colour changes in sugar-apples similar to the delay by edible coatings observed after treatment with some other naturally occurring biopolymers. However, differences in peel colour between coated and uncoated samples during the storage period at 10^{0}C in this study were more obvious than those obtained for sugar-apples and atemoya by other researchers [28, 29].

Effect of chitosan coating on the rate of weight loss of sugar-apples
One of the major factors responsible for the short shelf life of control sugar-apples was the high weight loss that caused shriveling and loss of brightness. Weight loss of coated and uncoated fruit increased with time of storage but was significantly reduced by chitosan coating (Fig. 4). The slower speed of weight loss in chitosan coated fruit and polyethylene film coated fruit might be partially caused by a blockade of dehydration [30].

Effect of chitosan coating on the respiration rate of sugar-apples
The respiration rates of fruit coated with chitosan and wrapped in polyethylene film are shown in Fig. 5. Coating of sugar-apples with chitosan was found to lower the respiratory rate in every set of experiments. Chitosan coating reduces the inflow and outflow of gas and water loss. When sugar-apples start to ripen, their higher respiratory rate results in a decrease of internal oxygen concentration, whereas that of carbon dioxide increases. The high concentration of carbon dioxide helps to reduce the respiration process in the produce. This accumulation of gases makes sugar-apple also more resistant to the chilling injury [5, 31]. It was observed that at all stages of storage, fruit protected in both ways showed a slightly lower respiratory rate than fruit only wrapped.

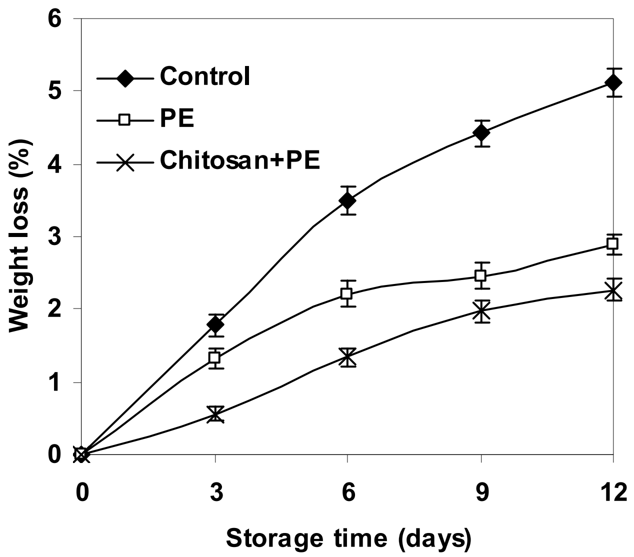

Figure 4. Effect of chitosan coating in combination with wrapping in polyethylene film (PE) on changes in rate of weight loss of sugar-apples during storage at 10^0C, compared with effect of polyethylene wrapping PE only and with control (no protective treatment).
Each value is the mean for five replicates, and vertical bars indicate the standard deviation.

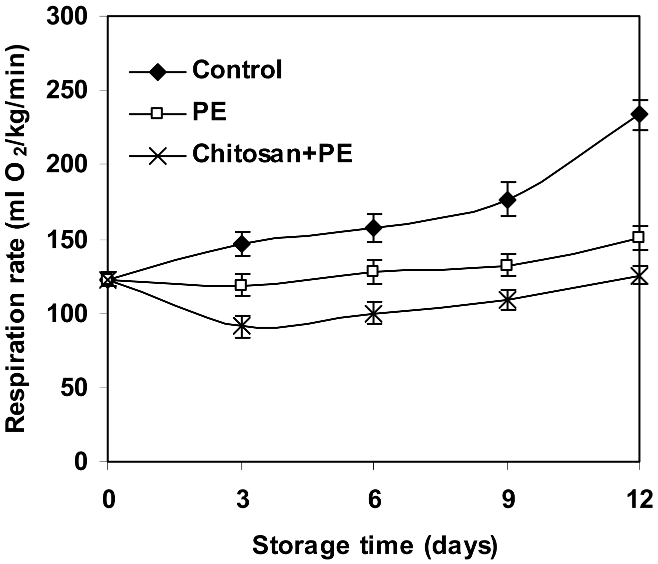

Figure 5. Effect of chitosan coating in combination with wrapping in polyethylene film (PE) on changes in the respiration rate of sugar-apples during storage at 10^0C, compared with effect of polyethylene wrapping PE only and with control (no protective treatment).
Each value is the mean for five replicates, and vertical bars indicate the standard deviation.

Effect of chitosan coating on total sugar content of sugar-apples

Changes in total sugar content of sugar-apples with storage time are shown in Fig. 6. On the first day of storage, the percentage of total sugar content was 5.8%. The concentration of total sugar increased in all samples over time during storage. This is probably the result of the conversion of starch into glucose and fructose during ripening [28].

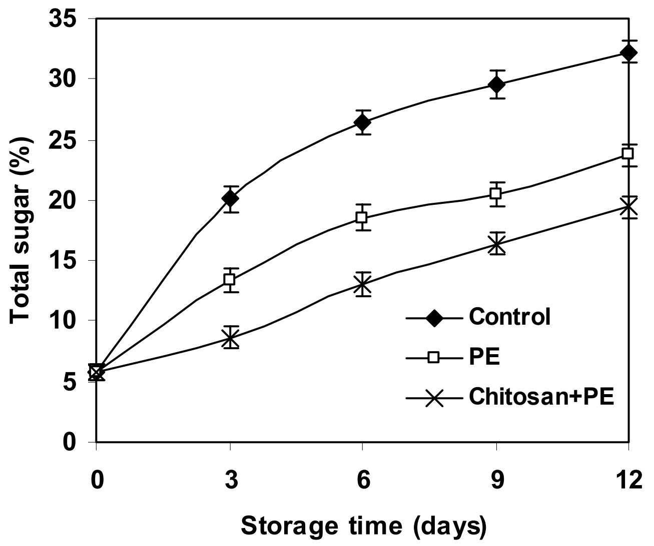

Figure 6. Effect of chitosan coating in combination with wrapping in polyethylene film (PE) on changes in total sugar content of sugar-apples during storage at 10^0C, compared with effect of polyethylene wrapping PE only and with control (no protective treatment).
Each value is the mean for five replicates, and vertical bars indicate the standard deviation.

There is a rise in total sugar content during custard-apple ripening and atemoya ripening as well as with the decline in starch content [3, 29, 32]. Throughout the storage period, the total sugar showed an increasing trend. On 12 days, total sugar level of control fruit was 32.3% of soluble solids, whereas total sugar level of coated fruit ranged between 19.3 and 23.7%. In the control fruit the total sugar content was found to increase faster than in the coated fruit. After combination coating with chitosan and polyethylene film a lesser increase in total sugar was observed, compared with wrapping in polyethylene film only. The reduced increase in sugar content is probably due to the fact that the thin layer of chitosan on the surface of fruit delays the degradation process [27, 33, 34].

Effect of chitosan coating on titratable acidity of sugar-apples

The change in titratable acidity of sugar-apples as a function of storage time is shown in Fig. 7. Titratable acidity of sugar-apples increased at the initial period of storage, and then decreased significantly after 6 days for control fruit or after 9 days for coated fruit. Titratable acidity of coated fruit decreased only slightly at the end of storage period. The delay in the use of organic acids in the enzymatic reactions of respiration can be explained as the result of a slow down of the sugar-apple's respiration rate due to the polymer wrapping. There was no significant difference in titratable acidity amongst coated fruit at the end of the storage period.

After 12 days of storage, the lowest value (0.11%) for titratable acidity was found in control fruit, whereas the highest value (0.16%) was found in polyethylene film coated fruit. In general, the acidity of the majority of fruit decreases during ripening and storage time. For sugar-apples the increase observed is characteristic although less than expected, since Pal and Kumar [2] observed a variation of titratable acidity from 0.08 to 0.25% citric acid for mature custard apple. These results are in agreement with the findings of Vishnu and Sudhakarda [3], Yamashita, *et al.* [29] and Batten, [32], on custard-apples and atemoya fruits who reported the increase of titratable acidity of *Annonaceae* fruit during the initial period of storage followed by a decrease.

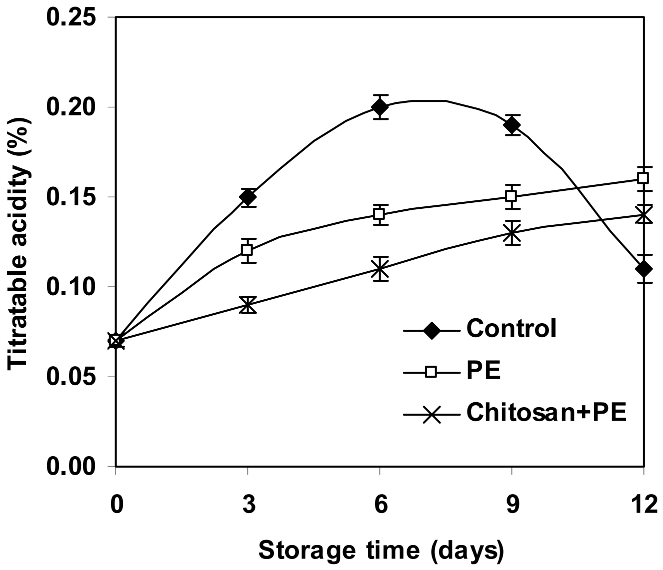

Figure 7. Effect of chitosan coating in combination with wrapping in polyethylene film (PE) on changes in titratable acidity of sugar-apples during storage at 10^0C, compared with effect of polyethylene wrapping PE only and with control (no protective treatment).
Each value is the mean for five replicates, and vertical bars indicate the standard deviation.

Effect of chitosan coating on changes in ascorbic acid content of sugar-apples

The ascorbic acid content increased significantly in the first stage of storage in both uncoated and coated fruit, as indicated by Fig. 8, and then decreased after 3 days for control fruit or after 6 days for polyethylene film wrapped fruit or after 9 days for 2.0% chitosan and polyethylene film protected fruit.

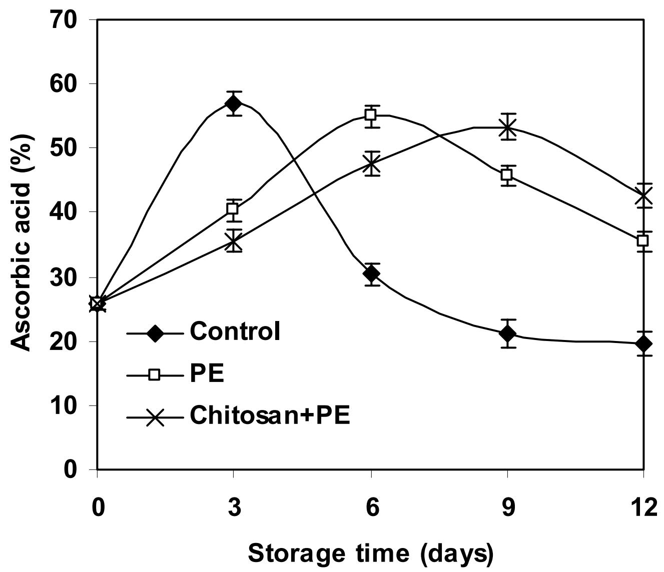

Figure 8. Effect of chitosan coating in combination with wrapping in polyethylene film (PE) on changes in ascorbic acid content of sugar-apples during storage at 10^0C, compared with effect of polyethylene wrapping PE only and with control (no protective treatment).
Each value is the mean for five replicates, and vertical bars indicate the standard deviation.

After 12 days of storage ascorbic acid content losses for sugar-apples coated with chitosan was significantly lower than those for control fruit. These results are in line with the study of changes in titratable acidity of sugar-apples. Ascorbic acid at the start of the experiment was 25.7 mg/100grams which increased with different treatments. Control fruit showed a maximum increase in ascorbic acid content to 56.9 mg/100grams after 3 days of storage, while the maximum increase for polyethylene film wrapped fruit (54.9 mg/100grams) was observed after 6 days and the maximum increase for 2.0% chitosan and polyethylene film protected fruit (53.3 mg/100grams) after 9 days. On the last day of storage, ascorbic acid content was 19.6 mg/100grams for the control while ascorbic acid contents ranged between 35.5 mg/100grams and 42.6 mg/100grams for the coated fruit. The results showed that sugar-apple coated with 2.0% chitosan and polyethylene film were both found to have higher ascorbic acid content than ones wrapped in polyethylene film only.

Conclusions

The effects of chitosan coatings on postharvest life of sugar-apples in PE wrapping at 10^{o}C can be summarized as follows:

Chitosan coatings extend the shelf-life of sugar-apples by reducing the rate of weight loss, retarding respiration rate and delaying changes of rind colour, total sugar, titratable acidity and ascorbic acid during storage. Sugar-apples coated with 2.0% chitosan and wrapped in polyethylene film maintain their quality characteristics better, as compared with wrapping by polyethylene film only. The lower storage temperature used in our study decreased respiration and resulted in more significant differences between coated and uncoated samples.

References

1. Benassi, G., Correa, G.A.S.F., Kluge, R.A. and Jacomino, A.P. (2003). Shelf life of custard apple treated with 1-methylcyclopropene – an antagonist to the ethylene action. ***Brazilian Archives of Biology and Technology,*** 46, 115-119.

2. Pal, D.K. and Kumar, P.S. (1995). Changes in the physicochemical and biochemical composition of custard apple (*Annona squamosa* L.) fruits during growth, development and ripening. ***Journal of Horticultural Science,*** 70, 569-572.

3. Vishnu, P.K.N. and Sudhakarda, R.D.V. (2000). Effect of storage temperature on ripening and quality of custard apple (*Annona squamosa* L.) fruits. ***The Journal of Horticultural Science and Biotechnology,*** 75, 546-550.

4. Prasanna, K.N.V., Rao, D.V.S. and Krishnamurthy, S. (2000). Effect of storage temperature on ripening and quality of custard apple (*Annona squamosa* L.) fruits. ***Journal of Horticultural Science and Biotechnology,*** 75(5): 546-550.

5. Broughton, W.J. and Guat, Tan (1979). Storage conditions and ripening of the custard apple *Annona squamosa* L. ***Scientia Horticulturae,*** 10(1): 73-82.

6. Mo, Yiwei, Gong, Deqiang, Liang, Guobin, Han, Ruihong, Xie, Jianghui and Li, Weicai (2008). Enhanced preservation effects of sugar apple fruits by salicylic acid treatment during post-harvest storage. ***Journal of the Science of Food and Agriculture,*** 88(15): 2693-2699.

7. Cisneros-Zevallos, L. and Krochta, J.M. (2002). Internal modified atmospheres of coated fresh fruits and vegetables: understanding relative humidity effects. ***Journal of Food Science,*** 67, 1990-1994.

8. Lee, J.Y., Park, H.J., Lee, C.Y. and Choi, W.Y. (2003). Extending shelf-life of minimally processed apples with edible coatings and antibrowning agents. ***Food Science and Technology,*** 36, 323-329.

9. Banks, N.H. (1984). Some effects of TAL Pro-Long coating on ripening bananas. ***Journal of Experimental Botany,*** 35, 127-137.

10. Amarante, C., Banks, N.H. and Ganesh, S. (2001). Effects of coating concentration, ripening stage, water status and fruit temperature on pear susceptibility to friction discolouration. ***Postharvest Biology and Technology,*** 21, 283-290.

11. Yonemoto, Y., Higuchi, H. and Kitano, Y. (2002). Effects of storage temperature and wax coating on ethylene production, respiration and shelf-life in cherimoya fruit. ***Journal of the Japanese Society for Horticultural Science,*** 71, 643-650.

12. Bai, J., Hagenmaier, R.D. and Baldwin, E.A. (2003). Coating selection for 'Delicious' and other apples. ***Postharvest Biology and Technology,*** 28, 381-390.

13. Hirano, S., Itakura, C., Seino, H., Akiyama, Y., Nonata, I., Kanbara, N. and Kawahami, T. (1990). Chitosan as an ingredient for domestic animal feeds. ***Journal of Agricultural and Food Chemistry,*** 38, 1214-1217.

14. El Ghaouth, A., Arul, J., Grenier, J. and Asselin, A. (1992). Antifungal activity of chitosan on two postharvest pathogens of strawberry fruits. ***Phytopathology,*** 82, 398-402.

15. Li, H. and Yu, T. (2001). Effects of chitosan on incidence of brown rot, quality and physiological attributes of postharvest peach fruit. ***Journal of the Science of Food and Agriculture,*** 81, 269-274.

16. Romanazzi, G., Nigro, F., Ippolito, A., Di Venere, D. and Salerno, M. (2002). Effects of pre- and postharvest chitosan treatments to control storage grey mold of table grapes. ***Journal of Food Science,*** 67, 1862-1867.

17. El Ghaouth, A., Arul, J., Ponnamapalam, R. and Boulet, M. (1991). Chitosan coating effect on storability and quality of fresh strawberries. ***Journal of Food Science,*** 56, 1618-1620.

18. Du, J.M., Gemma, H. and Iwahori, S. (1997). Effects of chitosan coating on the storage of peach, Japanese pear and kiwifruit. ***Journal of the Japanese Society for Horticultural Science,*** 66, 15-22.

19. Romanazzi, G., Nigro, F. and Ippolito, A. (2003). Short hypobaric treatments potentiate the effect of chitosan in reducing storage decay of sweet cherries. ***Postharvest Biology and Technology,*** 29, 73-80.

20. Khan, D. and Ali, S. (2007). Storage stability of persimmon fruits (*Diospyros kaki*) stored in different packaging materials. ***Journal of Agricultural and Biological Science,*** 2, 20-23.

21. Ramin, A. and Khoshbakhat, D. (2008). Effects of microperforated polyethylene bags and temperatures on the storage quality of acid lime fruits, 2008. ***American-Eurasian Journal of Agricultural and Environmental Science,*** 3 (4), 590-594.

22. Rathore, H.A., Masud, T. and Sammi, S. (2009). Effect of polyethylene packaging and coating having fungicide, ethylene absorbent and antiripening agent on the overall physico-chemical composition of Chaunsa white variety of mango at ambient temperature during storage. ***Pakistan Journal of Nutrition,*** 8, 1356-1362.

23. Habibunisa (1972). ***Indian Food Packer,*** 26, 13-17.

24. Dubois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A. and Smith, F. (1956). ***Anal Biochem,*** 28, 350–356.

25. Rangannan, S. (1991). Handbook of analysis and quality control of fruits and vegetable products. Tata McGraw Hill, New Delhi.

26. Chen, F., Li, Y.B. and Chen, M.D. (1986). The production of ethylene of litchi fruit during storage and its control. ***Acta Horticulturale Sinica,*** 13, 152-156.

27. Jiang, Y., Li, J. and Jiang, W. (2005). Effects of chitosan coating on shelf life of cold-stored litchi fruit at ambient temperature. ***LWT-Food Science and Technology,*** 38, 757-761.

28. Wongs-Aree, C. and Chunprasert, A. (2004). Storage quality of 'Neang' sugar apple treated with chitosan coating and MAP. ***Acta Horticulturae,*** 72, 300-305.

29. Yamashita, F., Miglioranza, L. and Miranda, L. (2002). Effects of packaging and temperature on postharvest of atemoya. ***Rev. Bras., Jaboticabal – SP***, 24, 658-660.

30. Shahidi, F., Arachchi, J.K.V. and Jeon, Y.J. (1999). Food applications of chitin and chitosans. ***Trends in Food Science and Technology,*** 10, 37-51.

31. Lurie, S. and Crisosto, C.H. (2005). Chilling injury in peach and nectarine. ***Postharvest Biology and Technology,*** 37, 195-208.

32. Batten, D.J. (1990). Effect of temperature on ripening and post-harvest life of fruit of atemoya (*Annona cherimola* Mill. x *A. squamosa* L.) cv. 'African Pride'. ***Scientia Horticulturae,*** 45(1-2): 129-136.

33. Devlieghere, F., Vermeulen, A. and Debevere, J. (2004). Chitosan: antimicrobial activity, interactions with food components and applicability as a coating on fruit and vegetables. ***Food Microbiology,*** 21(6): 703-714.

34. Pattanasiri, N., Kanlayanarat, S. and Kyu, K.L. (2002). Effects of chitosan coatings on storage life of mango (*Mangifera indica* L.). ***Advances in Chitin Science,*** 5, 505-511.